JOURNAL OF MARITIME RESEARCH

Vol XXI. No. II (2024) pp 449–455

ISSN: 1697-4840, www.jmr.unican.es

Ship Collision Probability in North Adriatic

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ARTICLE INFO

Article history:
Received 15 Apr 2024;
in revised from 24 Apr 2024;
accepted 16 May 2024.

Keywords:
Collision probability, Gulf of Trieste, IWRAP, Maritime safety, Roundabout.

ABSTRACT

Maritime safety has become a more and more important issue due to the increase in maritime traffic. Despite all efforts to reduce the risk of accidents, the number of them continues to increase especially when it comes to ship collisions. Considering the fact that the Adriatic Sea is recognized as a high-risk area in terms of accidents, new perspectives need to be used for determining collision probability in certain areas. The paper analyses a navigational area in the Gulf of Trieste, which represents exceptional importance and provides access to one of the most important ports in the Adriatic, the ports of Trieste and Koper. The research approach for determining collision probability has been based on the AIS data by using the IALA risk management tool – IWRAP. The aim of the paper was to determine the collision probability and, based on the results, to propose a solution to increase safety at sea in the Gulf of Trieste.

1. Introduction.

Maritime transport with more than 80% of world trade represents a significant part of the international supply chain and the global economy development (UNCTAD, 2022). Maritime trade is constantly increasing, leading to an increase in maritime traffic, which on the other hand increases the risk of accidents, especially the risk of collisions. Despite all efforts to increase safety at sea, the occurrence of maritime accidents is still increasing (EMSA, 2022). The Adriatic Sea, which constitutes the area of focus for this research, is considered a high-risk area in terms of accidents and casualties. The frequency of accidents in the Adriatic is five times higher than the world average (Kačić, 2011).

The most frequent type of maritime accident but also the most dangerous is ship collisions. Ship collisions pose a great danger to human life, as shown by the statistics of the European Maritime Safety Agency (EMSA), which indicate that from 2014 to 2021 collision as a type of maritime accident was the main event causing injuries and fatalities (EMSA, 2022).

There are several factors that can increase the risk of collisions in a certain area. One such area that poses a certain risk of accidents is located in the northern part of the Adriatic Sea, in the Gulf of Trieste, which serves as one of the main overseas gateways to Central and Eastern Europe. In the Gulf of Trieste are located ports of Koper and Trieste, the two largest ports in the northern Adriatic, and the port of Monfalcone, which has a considerable annual turnover of goods. In this area, there is a large concentration of maritime traffic with different routes at the approaches to the mentioned ports which increases the risk of collision.

Considering the importance of the Gulf of Trieste for the economy worldwide, the aim of this paper is to determine collision probability in that area. In order to make a quality survey, an analysis of maritime traffic in the navigation area was made. The research approach for determining collision probability has been based on the AIS data using the quantitative risk

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management tool, IALA Waterway Risk Assessment Program (IWRAP). Based on the results of the collision probability, the proposal for increasing safety at sea in the Gulf of Trieste was introduced.

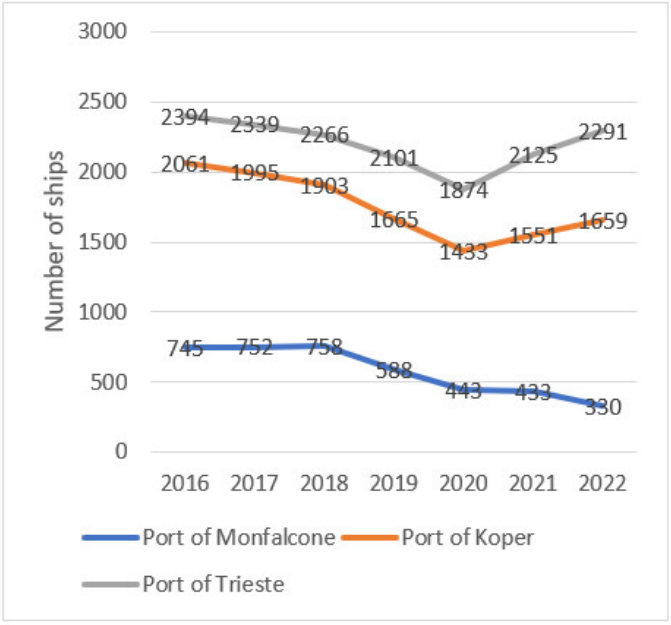
2. Background.

The top priority for the navigator on the ship should be to ensure safety during navigation. In practice, however, a statistical analysis shows that 80% of accidents at sea are caused by human error (Kim, 2020). In the study by Chauvin et al. (2013), which analysed 27 collisions between 1998 and 2012, it was found that the main cause of the collisions was decision-making errors related to the non-application of COLREG rules (Namgung and Ohn, 2022). Although the International Regulations for Preventing Collisions at Sea provide guidelines and regulations for determining the encounter situations between ships, most collision accidents occur in crossing situations (Silveira et al., 2013). Furthermore, in many research, the type of ship, the high density of maritime traffic, and the geographical area are among the most important factors influencing ship collisions (Silveira et al., 2013; Goerlandt et al., 2014; Antao et al., 2023). Taking these factors into account, the Gulf of Trieste represents an area of significant maritime traffic density in a relatively small area with multi-ship crossing situations.

The analysis of statistical accident data in the observed area of 13 years data shows that general cargo ships, bulk carriers, and container ships cause the most ship collisions (Antao et al., 2023). In the analysis of the observed area, the mentioned ships represent a significant share. In the port of Koper, general cargo ships, bulk carriers and container ships account for 50% of the traffic (Marine Traffic, Koper Luka, 2023), while in the port of Trieste is 38% (Marine Traffic, Trieste Port, 2023) and in the port of Monfalcone 31% (Marine Traffic, Monfalcone Port, 2023). The mentioned types of ships are categorized by large lengths which can very often affect the flexibility and timeliness of steering and be crucial in certain situations and waterways. Container ships belong to the category of ships with the largest length, and since the port of Koper achieves the largest annual container traffic in the Mediterranean with all other types of ships in the observed ports, collision probability in the Gulf of Trieste can be significant.

On certain stretches of the waterway or in port areas, the high density of maritime traffic can increase the probability of ship collisions (Rong et al., 2021, Xia et al. 2021). Maritime traffic density refers to the number of ships crossing a specific sea area within a particular time period. It is assessable through vessel tracking systems, such as the Automatic Identification System (AIS). In the observed navigation area of the Gulf of Trieste, there is a significant density of maritime traffic. Different types of ships arrive in the observed ports, with an average annual number of 4,530 arrivals from 2016 to 2022 (Figure 1), which is equivalent to 24 ships per day (Marine Traffic, Koper Luka, Trieste Port, 2023).

Figure 1: Ships arrival from 2016 to 2022.

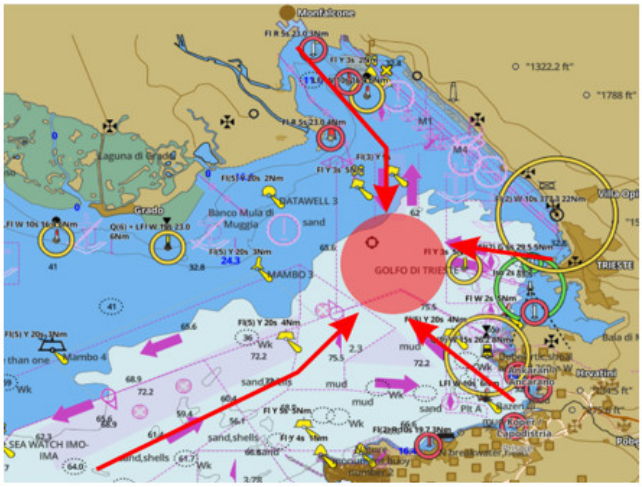


Source: Marine Traffic.

The statistical data includes only commercial vessels and does not account for vessels used for nautical tourism, fishing, and other types of ships that also constitute a substantial part of maritime traffic.

The traffic flows can vary in certain geographical locations. In the Gulf of Trieste, there is a traffic flow that follows the established mandatory Traffic Separation Schemes (TSS). Following established ships' routeing measures proceeding to and out of ports, ships can meet at a point called a "black-spot". Black-spots are places where near misses or accidents occur more frequently than at other locations (Zhang et al., 2021). One such area is located before entering the "TSS Gulf of Trieste", where ships arriving but also departing to/from all three ports can meet at the same position (Figure 2).

Figure 2: Black-spot in the Gulf of Trieste.



Source: Authors.

The width of the Gulf of Trieste is approximately 12 nautical miles where some of the most major ports of the Adriatic Sea are situated. Navigating toward or from these ports, ships can encounter a lot of crossing situations from different directions.

Considering that the Gulf of Trieste represents an area of significant maritime traffic density with multi-ship crossing situations with different responsibilities between ships, the probability of collision needs to be determined in order to evaluate the level of navigational safety.

3. Collision probability.

The collision probability can be defined as the probability of an event where a ship fails to give way (Kuroda et al, 1982). In those situations, the consequences can be significant especially where are involved large vessels. Considering the fact that collisions account for more than a third of all accidents, it is important to estimate the probability of collision in order to make recommendations and find a way to reduce accidents (EMSA, 2022). Numerous research studies have estimated collision probability using various models, of which the IWRAP program has proven successful in estimating collision risk and probability in certain area (Dzikowski et al., 2014; Čorić et al., 2021; Handani et al., 2018). In the paper (Vukša et al., 2022) authors analyse two different methods of estimating the potential collisions at sea, analytical and simulation approaches. IWRAP program, as an analytical approach, has shown good results in estimating potential collision at sea.

IWRAP is currently one of the most widely used computer simulation programs for calculating collision and grounding frequencies of vessels based on information about traffic volume / composition, route geometry and bathymetry (IALA, 2023). IWRAP approach is based on the mathematical models of Macduff (1974), Fujii (1974), and Pedersen (1995). Fuji and MacDuff are considered pioneers in the assessment of the frequency and probability of collisions. During the 1970s, they proposed a collision frequency model, which is still the most commonly used model today (Kawashima et al. 2022).

In order to determine the collision frequency (λCol) these frequency models entail the calculation of the geometric number of collision candidates (NG) which is subsequently multiplied by the causation factor (PC):

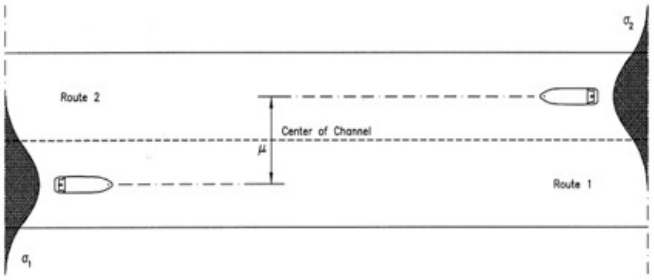
$$\lambda Col = PC * NG \tag{1}$$

Collisions can be roughly divided into two types (IALA, 2023):

- collisions along the route segment, such as overtaking or head-on collisions, and
- collisions when two routes cross each other, merge, or intersect within a bend of a fairway.

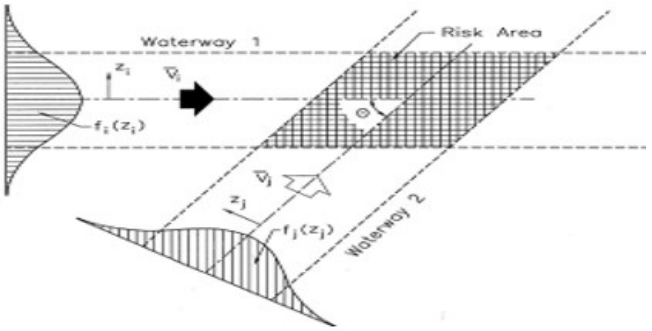
The approach to compute the number of collision candidates (NG) differs for these two types. In the first type, the geometric number of collision candidates depends on the lateral traffic dispersion along the route, whereas in the other type, it remains unaffected by the traffic spread (Figure 3 and Figure 4).

Figure 3: Definition of μ ratio and traffic distribution.



Source: IALA, 2023.

Figure 4: Crossing waterways with risk area of ship-ship collision.



Source: IALA, 2023.

Comparing Figure 3 and Figure 4, the procedure for the calculation of the collision is different. In Figure 3, it depends on the lateral traffic spread on the route which is not the case in Figure 4. In Figure 3, the likelihood of the trajectories of two ships will overlap depending on the lateral dispersion. The larger the μ value, there is lower probability of collision. Figure 4 illustrates that, despite the influence of traffic on the "risk area," the probability of ships encountering each other remains unaffected.

Head-on and overtaking collisions (Figure 4) along the route depend on (IALA, 2023):

LW – length of the segment

Qi(1), Qj(2) - the number of passages per time unit for each ship type and size in each direction

Vi(1), Vj(2) – ship speed

fi (1)(y), fj (2)(y) - geometrical probability distribution of the lateral traffic spread on the route

When considering head-on collisions, the count of geometric collision candidates for ships sailing along the route segment in both directions can be expressed as follows (IALA, 2023):

$$N_G^{head-on} = L_W \sum_{i,j} P_{G\,i,j}^{head-on} \frac{V_{i,j}}{V_i^{(1)} V_j^{(2)}} (Q_i^{(1)} Q_j^{(2)}) \tag{2}$$

Vij presents relative speed between the vessels while PG the probability of collision in ahead of meeting situation. The frequency of head-on collisions ($\lambda_{Col}^{head-on}$) is determined by multiplying the geometric number of collisions, ($N_G^{head-on}$), as defined in Equation (2), by the causation factor for head on collisions ($P_C^{head-on}$).

In the case of overtaking collisions, the number of geometric candidates is expressed by Eq. (2) using the relative speed $V_{ij}=V_i^{(1)}-V_j^{(2)}$. If Vij is less than zero, it indicates that vessel i will not be able to overtake vessel j. The angle between the two lanes determines the frequency of crossing collisions (Figure 5). In the case of crossing collisions, the number of geometric collision candidates can be represented as follows (IALA, 2023):

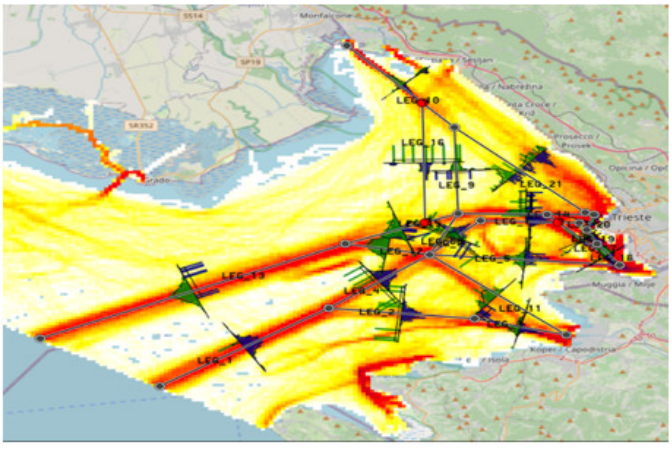
$$N_G^{crossing}=\sum_{i,j}\frac{Q_i^{(1)}Q_j^{(2)}}{V_i^{(1)}V_j^{(2)}}D_{ij}V_{ij}\frac{1}{sin\theta} \quad for \;\; 10^\circ<|\theta|<170^\circ \tag{3}$$

Dij element represents the apparent collision diameter.

For determination of the collision probability in the paper, the AIS data for the month of October 2022 have been used. The analysis of the data showed that the 10th month of last year (2022) in the Gulf of Trieste had the highest cargo turnover, and therefore was selected for the collision risk assessment (TMT, 2023; SiStat, 2023).

In the first step, the area model of Gulf of Trieste is defined. Furthermore, traffic AIS data has been imported in the IWRAP application, followed by creating a traffic density plot. The next step, based on the traffic density plot, involves plotting the legs on the map where the highest amount of traffic is. In the final step, before running a model, precise bathymetry is defined, which is required for the functioning of IWRAP.

Figure 5: IWRAP model for Gulf of Trieste.



Source: Authors.

Collision probability results in Gulf of Trieste has been presented in the following table. The probabilities are provided for various navigation scenarios, with the final column presenting the predicted number of incidents per year between each collision.

Table 1: Probabilities of collision results in Gulf of Trieste.

Crossing

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	2,07E-05	9,15E-05	4,51E-06	7,41E-08	1,06E-05	8,65E-07	4,52E-06	2,59E-06	1,35E-04
General cargo	1,67E-04	3,19E-04	1,24E-05	1,24E-07	9,95E-05	5,48E-06	3,63E-05	1,35E-05	6,53E-04
Bulk carrier	2,08E-05	4,45E-05	3,24E-05	9,67E-08	5,54E-06	5,56E-06	3,34E-06	2,24E-05	1,35E-04
Container ship	1,92E-04	7,56E-05	4,67E-05	4,56E-08	2,22E-05	6,54E-06	2,76E-06	3,45E-05	3,80E-04
Passenger	9,82E-06	2,23E-05	4,85E-07	8,35E-09	3,55E-06	2,97E-07	2,39E-06	2,96E-07	3,91E-05
Fast ferry	3,05E-07	2,92E-07	1,23E-08	3,61E-11	7,99E-08	1,74E-09	4,08E-08	9,64E-09	7,41E-07
Support	3,65E-05	4,02E-04	7,77E-06	1,56E-07	7,23E-05	4,37E-06	4,46E-05	4,92E-06	5,73E-04
Fishing	1,14E-06	7,76E-06	3,31E-07	2,39E-09	4,21E-06	2,61E-10	5,95E-07	3,34E-07	1,44E-05
Pleasure	1,36E-05	8,64E-05	3,27E-06	4,65E-08	4,41E-05	6,15E-07	1,22E-05	3,51E-06	1,64E-04
Other	8,81E-06	4,79E-05	8,35E-07	1,75E-08	5,95E-06	5,03E-07	4,24E-06	6,02E-07	6,89E-05
Sum	4,71E-04	1,10E-03	1,09E-04	5,71E-07	2,68E-04	2,42E-05	1,11E-04	8,27E-05	2,16E-03

HeadOn

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	8,02E-05	3,42E-05	2,11E-06	3,31E-09	9,72E-06	9,27E-06	1,15E-05	4,17E-07	1,47E-04
General cargo	3,42E-05	1,16E-04	8,65E-06	3,36E-08	4,49E-05	2,58E-05	4,89E-05	3,99E-06	2,82E-04
Bulk carrier	4,43E-05	2,45E-05	4,56E-06	4,45E-08	5,78E-05	5,67E-06	3,50E-06	4,58E-06	1,45E-04
Container ship	6,75E-05	3,67E-05	5,67E-06	3,21E-08	4,45E-06	4,31E-06	2,12E-06	3,59E-06	1,24E-04
Passenger	2,11E-06	8,65E-06	1,88E-05	1,42E-09	6,38E-05	1,03E-06	9,72E-06	8,79E-06	1,13E-04
Fast ferry	3,31E-09	3,36E-08	1,42E-09	4,00E-11	1,04E-09	1,60E-08	1,74E-08	1,47E-09	7,43E-08
Support	9,72E-06	4,49E-05	6,38E-05	1,04E-09	2,54E-04	4,26E-07	4,39E-05	3,45E-05	4,51E-04
Fishing	9,27E-06	2,58E-05	1,03E-06	1,60E-08	4,26E-07	2,55E-07	8,58E-07	2,41E-07	3,79E-05
Pleasure	1,15E-05	4,89E-05	9,72E-06	1,74E-08	4,39E-05	8,58E-07	2,85E-05	3,57E-06	1,47E-04
Other	4,17E-07	3,99E-06	8,79E-06	1,47E-09	3,45E-05	2,41E-07	3,57E-06	4,76E-06	5,63E-05
Sum	2,59E-04	3,44E-04	1,23E-04	1,51E-07	5,13E-04	4,79E-05	1,53E-04	6,44E-05	1,50E-03

Overtaking

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	3,32E-05	4,99E-04	2,32E-05	4,05E-07	7,60E-06	2,57E-07	5,95E-06	3,19E-06	5,73E-04
General cargo	1,52E-05	4,65E-04	3,93E-05	9,11E-07	4,93E-05	3,93E-06	2,46E-05	5,44E-06	6,04E-04
Bulk carrier	2,42E-05	4,72E-04	3,16E-05	6,82E-07	5,16E-05	4,11E-06	3,33E-05	3,40E-06	6,21E-04
Container ship	3,16E-05	3,58E-04	2,88E-05	5,18E-07	3,58E-05	5,96E-06	2,76E-06	2,54E-06	4,66E-04
Passenger	5,09E-07	1,29E-05	7,76E-07	2,40E-08	4,98E-07	2,36E-09	5,99E-07	2,80E-07	1,56E-05
Fast ferry	0	3,01E-07	1,70E-08	0	0	0	2,08E-09	8,95E-09	3,29E-07
Support	1,55E-05	5,31E-05	1,60E-05	2,80E-08	3,85E-06	0	3,17E-06	3,47E-06	9,51E-05
Fishing	4,60E-05	2,10E-04	8,10E-06	9,16E-08	8,92E-07	0	3,05E-06	1,65E-06	2,70E-04
Pleasure	1,66E-05	1,35E-04	1,51E-05	1,56E-07	3,14E-05	2,05E-07	8,38E-06	2,19E-06	2,09E-04
Other	4,70E-06	2,86E-05	1,41E-05	1,33E-08	4,64E-05	0	1,47E-06	3,39E-07	9,56E-05
Sum	1,88E-04	2,23E-03	1,77E-04	2,83E-06	2,27E-04	1,45E-05	8,33E-05	2,25E-05	2,95E-03

Merging

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	6,89E-06	1,19E-04	4,30E-06	7,90E-08	8,39E-07	7,60E-07	1,71E-06	8,65E-07	1,34E-04
General cargo	1,98E-04	2,81E-04	9,52E-06	9,15E-08	3,47E-06	2,28E-06	5,45E-06	2,33E-06	5,02E-04
Bulk carrier	3,57E-05	2,54E-04	7,58E-06	8,12E-08	6,58E-07	6,62E-06	2,18E-06	8,23E-06	3,15E-04
Container ship	2,18E-04	3,59E-04	6,62E-06	9,09E-08	7,12E-06	3,46E-07	3,46E-06	3,46E-07	5,95E-04
Passenger	6,98E-06	9,11E-06	2,89E-07	2,28E-09	1,66E-07	9,70E-08	2,00E-07	7,34E-08	1,69E-05
Fast ferry	3,04E-07	2,46E-07	6,77E-09	0	1,38E-09	0	3,78E-09	2,27E-09	5,64E-07
Support	2,82E-06	7,87E-06	4,56E-07	1,21E-09	2,04E-08	1,19E-08	1,27E-07	5,26E-08	1,14E-05
Fishing	1,03E-06	2,77E-06	1,15E-07	0	7,16E-09	0	3,44E-08	1,73E-08	3,97E-06
Pleasure	8,16E-06	1,40E-05	4,74E-07	2,28E-09	1,20E-07	4,30E-08	2,59E-07	1,16E-07	2,32E-05
Other	3,11E-06	5,73E-06	1,92E-07	1,69E-09	5,44E-08	2,48E-08	1,02E-07	4,45E-08	9,26E-06
Sum	4,81E-04	1,05E-03	2,96E-05	3,50E-07	1,25E-05	1,02E-05	1,35E-05	1,21E-05	1,61E-03

Bend

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	0	0	0	0	0	2,77E-07	0	0	2,77E-07
General cargo	0	0	0	0	0	1,82E-06	1,57E-07	0	1,98E-06
Bulk carrier	0	0	0	0	0	3,24E-06	2,34E-08	0	3,26E-06
Container ship	0	0	0	0	0	2,92E-07	1,26E-07	0	4,18E-07
Passenger	0	0	4,42E-06	0	1,56E-05	2,92E-08	6,36E-07	1,15E-06	2,18E-05
Fast ferry	0	0	0	0	0	0	0	0	0
Support	0	0	1,53E-05	0	5,41E-05	1,19E-08	2,15E-06	4,01E-06	7,56E-05
Fishing	3,39E-07	2,10E-06	3,42E-08	0	7,16E-09	0	0	1,05E-08	2,49E-06
Pleasure	0	4,11E-07	7,40E-07	0	2,40E-06	0	9,37E-08	1,76E-07	3,82E-06
Other	0	0	1,60E-06	0	5,62E-06	1,33E-08	2,19E-07	4,01E-07	7,85E-06
Sum	3,39E-07	2,51E-06	2,21E-05	0	7,77E-05	5,68E-06	3,41E-06	5,75E-06	1,18E-04

Total Collisions

Striking/Struck	Oil products	General cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Oil products	1,41E-04	7,44E-04	3,41E-05	5,61E-07	2,87E-05	1,14E-05	2,36E-05	7,05E-06	9,90E-04
General cargo	4,14E-04	1,18E-03	6,99E-05	1,16E-06	1,97E-04	3,93E-05	1,15E-04	2,79E-04	2,30E-03
Bulk carrier	3,25E-04	2,45E-04	4,77E-05	6,32E-06	3,02E-04	2,06E-05	1,36E-05	1,05E-05	9,71E-04
Container ship	1,78E-04	1,25E-03	3,13E-05	5,79E-06	2,11E-05	2,49E-05	2,45E-05	2,16E-05	1,56E-03
Passenger	1,94E-05	5,30E-05	2,47E-05	3,60E-08	8,36E-05	1,46E-06	1,35E-05	1,06E-05	2,06E-04
Fast ferry	6,12E-07	8,72E-07	3,75E-08	7,62E-11	8,23E-08	1,77E-08	6,40E-08	2,23E-08	1,71E-06
Support	6,45E-05	5,08E-04	1,03E-04	1,86E-07	3,85E-04	4,82E-06	9,40E-05	4,70E-05	1,21E-03
Fishing	5,78E-05	2,49E-04	9,62E-06	1,10E-07	5,54E-06	2,55E-07	4,54E-06	2,26E-06	3,29E-04
Pleasure	4,98E-05	2,84E-04	2,93E-05	2,22E-07	1,22E-04	1,72E-06	4,95E-05	9,57E-06	5,46E-04
Other	1,70E-05	8,62E-05	2,55E-05	3,40E-08	9,25E-05	7,82E-07	9,60E-06	6,15E-06	2,38E-04
Sum	1,27E-03	4,60E-03	3,75E-04	1,44E-05	1,24E-03	1,05E-04	3,48E-04	3,94E-04	8,34E-03

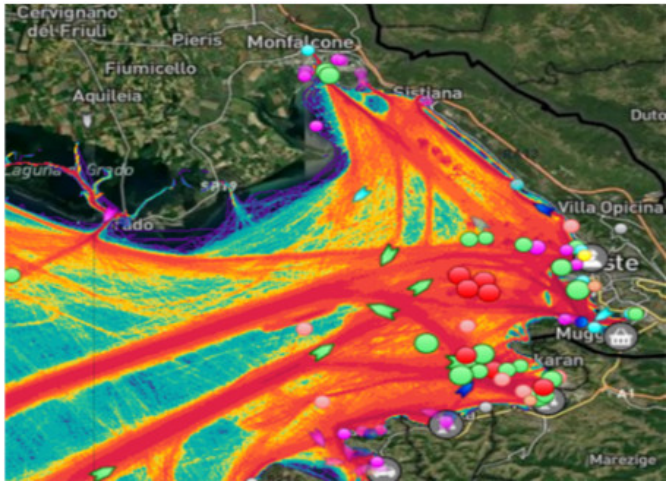
Source: Authors.

Based on the results, in the concluding section, the sum of all probabilities indicates that, according to the traffic analysis, there is an average expectation of 0,00834 collisions per year which is equivalent to one collision every 267 years. Although the probability of a collision in the observed area may be considered low, the authors in the paper suggest a way to enhance safety in the Gulf of Trieste.

4. Discussion.

As already mentioned, the most critical location in the Gulf of Trieste is situated before/after the "TSS Gulf of Trieste" (Figure 2). Through the analysis of maritime traffic monitoring in this location, the navigation of large vessels passing each other at close distances is evident (Figure 6).

Figure 6: Maritime traffic in Gulf of Trieste 28.07.2023.



Source: Marine Traffic.

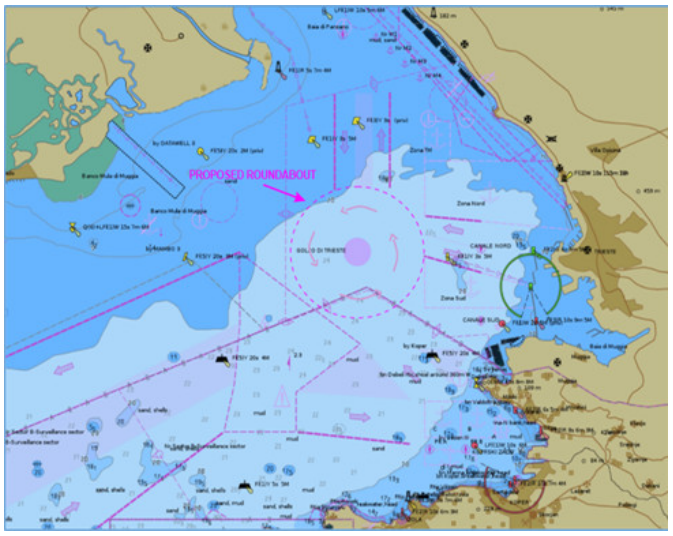
The authors consider that collision probability in the observed area can be reduced with the implementation of ships' routeing systems. Ships' routeing systems represent a crucial role in improving safety at sea, ensuring efficient navigation and preserving the marine environment. One of the elements which are used in ships' routeing systems is the roundabout. Roundabout represent a separation point or circular separation zone and a circular traffic lane with defined limits (IMO, 2023). Considering that ships from various directions approach or depart from ports in a small area, the authors believe that implementing a roundabout could further reduce the probability of collisions and increase maritime safety (Figure 7).

When arriving and departing to/from the port, instead of the intersection of vessel routes, they enter in a traffic separation scheme in which they sail in a counter-clockwise direction while avoiding undesirable situations of vessels crossing each other's bows at close distances.

Conclusions.

Based on the comprehensive analysis of maritime traffic in the northern part of the Adriatic Sea, especially in the Gulf of Trieste, it is evident that this region plays a decisive role as one of the most important gateways to Central and Eastern Europe. With the constant increase in maritime trade and related increase in maritime traffic, the risk of accidents is increasing as well. Maritime safety, considering the potential consequences that can occur, represents an imperative in the maritime industry. One of the most common causes of decreasing of maritime safety is ship collisions as a type of maritime accident. Different ship trajectories with crossing situations pose a major challenge in the Gulf of Trieste, increasing the likelihood of collisions. In view of the importance of the Gulf for maritime trade, a collision probability was determined using the IWRAP tool. Even though the collision probability can be categorized as low, the authors believe that the collision probability can be further reduced by implementing a roundabout as a ship's routeing measure. The implementation of such a system would involve defining specific routes and guidelines for ship navigation, ensuring a safer and more organized flow of maritime traffic. Further research should assess the grounding probability to consolidate the results of accidents obtained with the IWRAP tool.

Figure 7: Proposed roundabout in the Gulf of Trieste.



Source: Authors.

Funding.

This paper was funded under the project line ZIP UNIRI of the University of Rijeka, for the project UNIRI-ZIP-2103-15-22.

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